Magnetic Field Induced Space-Charge-Limited Current Flow in Disordered Ultra-thin Films

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Electronic systems such as doped semiconductors and disordered metals, which exhibit electrical versions of glass behavior, are often described as Coulomb or charge glasses. There is a substantial literature describing hysteretic, slow non-exponential relaxation, and memory effects in these systems. We have found a dramatic, parallel magnetic field induced glass-like phenomenon in quench-condensed ultrathin films of amorphous Bi (*a*-Bi), which manifests itself as a field-induced space-charge-limited flow of current. The sheet resistances of the films were never less than $10^5\Omega$ at 300 mK, and superconductivity is not involved.

Four-terminal measurements were carried out using afixed current of 7 x 10^{-11}A. In zero magnetic field, a voltage developed in response to applying current in a time the order of the RC time constant of the complete measuring circuit. In parallel fields above a certain temperature-dependent threshold, and at times later than the RC time constant, the measured voltage continued to change in a manner that was not exponential in time.

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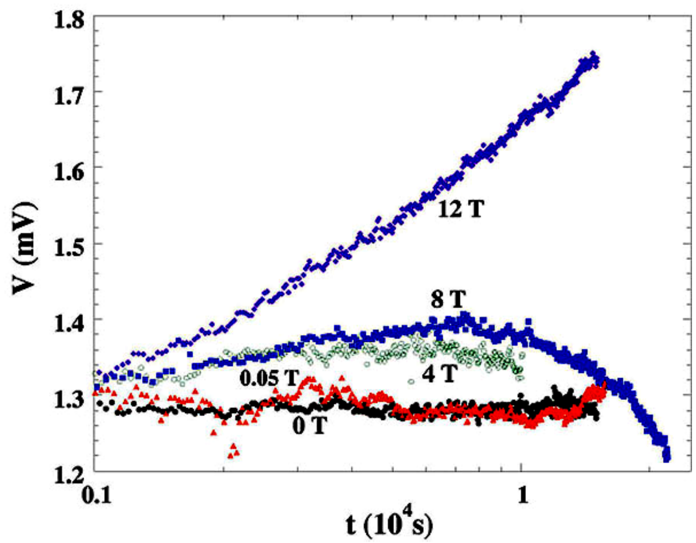

Voltage vs. time at T=50mK for an 11.38 Å thick film in zero magnetic field and in fields of 0.02, 0.05, 0.1, 1.0, 4, 8, and 12T. In zero magnetic field this film's sheet resistance was greater than 10^7 Ω at 50 mK.

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For some magnetic fields the voltage is a nonmontonic function of time. This magnetic field induced behavior is nearly identical to that found in space-charge-limited current flow produced by trapping sites. A space-charge front forms and migrates away from the leads. The electric field and measured voltage increase as it moves towards the voltage leads. When the front moves into the space between the leads the measured voltage falls. In the highest fields the front moves so slowly that it never reaches the voltage leads during the time of measurement. These effects are confined to the thinnest films at temperatures below 200mK.

We have speculated that the observed effects result from a collective state occurring in a disordered, spin-polarized, two-dimensional electronic system.

Education:

The measurements and analysis were carried out by Luis Hernadez, Kevin Parendo, and Dr. Anand Bhattacharya. Dr. Hernandez, who received his Ph.D. in December 2002, is now a member of the technical staff of the Naval Weapons Laboratory at China Lake. Mr. Parendo is a senior graduate student. Dr. Bhattacharya is a postdoctoral student.

Outreach:

Professor Goldman,as Department Head supports an outreach activity called the *Physics Force*. This group performed for aggregate audiences exceeding 40,000 during the past academic year. Dr. Bhattacharya has performed with the force, which now has two active teams in order to meet the demand for performances.